Visit from JAXA to NASA MSFC:

The Engines Element & Ideas for Collaboration

W.D.Greene, XP20
Engines Element Associate Manager
Space Launch Systems Program
NASA MSFC

22 April 2013

The Engines Element and Today's Participants

Exploration Systems Directorate (NASA Headquarters)

MPCV/Orion Program (NASA JSC)

Ground Systems Program (NASA KSC)

Space Launch System (SLS) Program (NASA MSFC)

Spacecraft and Payloads Element

Stages Element

Boosters Element

Engines Element

RS-25
Core Stage Engine

J-2X
Upper Stage Engine

Mike Kynard

Bil Greene

Dan Thompson

Joe Leahy

Matt Devine

NASA Marshall Space Flight Center Engineering Directorate

NASA Marshall Space Flight Center Safety and Mission Assurance (S&MA) Directorate

Top-Level Assumptions

- **This activity will be conducted by JAXA in support of the NASA Space Launch System Program**
  - JAXA is responsible for fulfilling the development objective
  - NASA is responsible for insight to enable a smooth transition from a development activity into an implemented facet of the exploration initiative

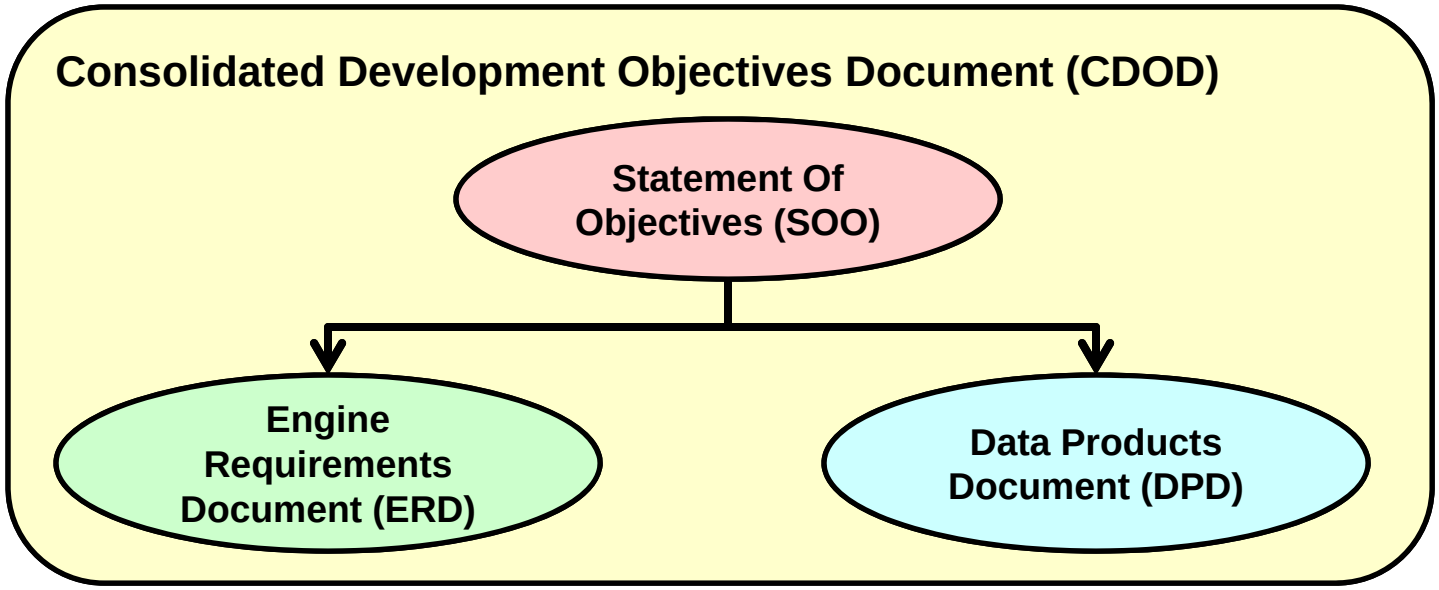
- **The specific objective of the effort (with respect to engines) is the development of a high-performance, 60,000-lbf, liquid hydrogen / liquid oxygen rocket engine for use with human-rated missions**

- **The development effort scope…**
  - Will achieve a ready-for-certification level of maturity with regards to design, development, fabrication, and associated infrastructure
  - Will include the entire engine system except for the engine controller unit

- **For now, what follows in terms of engine certification and production planning is to be left open for later discussion**

Establishing a Collaborative Relationship

- In order to promote and facilitate a productive, collaborative relationship, the Engines Element has assembled a draft "Consolidated Development Objectives Document"



- The intent is to clarify expectations
- Details of the constituent pieces will be discussed in subsequent charts

Statement of Objectives (SOO)

- **The SOO presents the expected, general work scope of the task**

- **System Design, Development, and Fabrication**
  - Design, develop, and fabricate or procure MB-60 component hardware compliant with the imposed technical requirements and in sufficient quantities to fulfill the overall MB-60 development effort
- **System Development, Assembly, and Test**
  - Manage the scope of the development, assembly, and test-related activities for MB-60 development
  - This scope includes engine-level development planning, engine assembly and disassembly, test planning, engine testing, inspection, anomaly resolution, and development of necessary ground support equipment and special test equipment
- **System Integration**
  - Provide coordinated integration in the realms of engineering, safety, quality, and manufacturing disciplines across the scope of the MB-60 design and associated products development
  - Safety and Mission Assurance, structural design, fracture control, materials and processes, thermal analysis
- **Systems Engineering and Analysis**
  - Manage and perform Systems Engineering and Analysis to provide rigor and structure to the overall design and development effort for the MB-60
  - Milestone reviews, requirements management, system analysis, program management support
- **Program Management**
  - Manage, plan, and coordinate the activities across all portions of the MB-60 work scope by providing direction for program administration, business management, and supplier management

Engine Requirements Document (ERD)

- **The ERD presents a minimum set of technical requirements for the engine**

- **Performance**
  - Nominal Vacuum Thrust
  - Thrust Precision
  - Throttling
  - Vacuum Specific Impulse
  - Nominal Mixture Ratio
  - Mixture Ratio Precision
- **Functionality**
  - Start
  - Shutdown
  - Mission Profile (restarts)
  - Minimum Net Positive Suction Pressure
  - Gimbal Flexure
  - Pressurization Flow
- **Characteristics**
  - Mass
  - Dimensions
  - Life – Starts
  - Life – Seconds
  - Continuous Firing Duration
  - Reliability
- **Design and Construction**
  - Strength and Life Design
  - Mechanism Design
  - Fracture Control
  - Materials and Processes
- **Interfaces and Environments**
  - Performance and Induced Environments

- **It is likely that this minimal list could grow as the overall stage concept matures so that it eventually includes greater interface details**

- **Verification requirements section left open for future discussion**

Data Products Document (DPD)

- **The DPD describes the minimum data products necessary to allow for sufficient and appropriate insight into the development effort**

- **Each of these products provides either greater clarity at the detailed, discipline level or explanation of the fulfillment of key development goals**

  - Structural Assessment Plan
  - Structural Strength and Fatigue Analysis Reports
  - Fracture Control Plan
  - Fracture Control Reports
  - Materials and Processes Selection, Implementation, and Control Plan
  - Material and Process Identification and Usage List
  - Material Usage Agreements
  - Thermal Design Data Book
  - Propulsion System Development Plan
  - Engine System Test Reports
  - Product Definition Data and Associated Lists
  - Engine System Specification
  - Verification Compliance Reports
  - Configuration Management Plan
  - System Safety Plan
  - Quality Assurance Plan
  - Hazards Analysis
  - Failure Modes and Effects Analysis and Critical Items List

A Perspective on "Human Rating"

- **A key feature for MB-60 to be developed here is that it is to be used as part of a human-rated launch architecture**

- **This fact requires a handful of considerations that the draft Consolidated Development Objectives Document addresses directly…**

- **Design and Development**
  - Specific technical requirements
  - Design and construction standards
  - System safety program

The primary consideration here is redundancy and this is mostly an influence on the engine controller which assumed to not be a part of the development effort.

Specific standards imposed and a compliance validation process applied as described on subsequent charts.

Failure modes and effects analysis and hazards analysis (consistent with SLS Program) part of SOO and DPD

- **Test and Evaluation**
  - Structured verification planning
  - Component and system development testing

Requirements management and requirements verification planning and reporting part of SOO and DPD

Component and system testing part of SOO including, through the DPD, the development of a Engine Development Plan where the detailed scope is explained

- **Development Management**
  - Quality Management
  - Configuration Management

Through the SOO and DPD both quality and configuration management plans are developed and implemented. Collaborative acceptability of these management systems is accomplished in a manner analogous to compliance validation for technical standards.

Compliance Validation for Technical Standards

- **Four design and construction standards imposed by the ERD with the language: "The MB-60 shall meet the intent of the requirements of…"**
  - Structural design, NASA-STD-5012
  - Mechanisms design, NASA-STD-5017
  - Fracture control, NASA-STD-5019
  - Materials and processes, NASA-STD-6016

- **The phrase "meets the intent" indicates use of a compliance validation process**

- **Step 1: Develop technical plans that describes how the intent of the imposed standards are to be met.**
  - Plans are described in the SOO and DPD

- **Step 2: Collaborate with NASA to ensure that the proposed approaches meet the needs and expectations of NASA**

- **Step 3: Generate technical reports consistent with collaborated plans**
  - Reports are described in the SOO and DPD
  - Reports act as verification compliance reports against the ERD requirements

Compliance Validation for Programmatic Requirements

- **Analogous compliance validation process proposed for requirements imposed on items other than the MB-60 engine, i.e., management processes and associated products**
  - Quality management, SLS-RQMT-014
  - Configuration management
  - Hazards analysis, SLS-RQMT-015
  - Failure modes and effects analysis / critical items list (FMEA/CIL), SLS-RQMT-016

- **For quality management and configuration management, develop a plan and collaborate with NASA to ensure that the proposed approaches meet the needs and expectations of NASA**

- **For hazards analysis and FMEA/CIL, develop draft examples of these products and then collaborate with NASA to ensure that the proposed approaches meet the needs and expectations of NASA**

- **These plans and associated products listed within the SOO and DPD**

Proposal Expectations

- **In order to allow for a thorough and fair evaluation of the final proposal, the following constituents are expected:**

- **Conceptual engine design**
  - Brief description of progress to date

- **Preliminary development plan**
  - How do you plan to get from the starting point to the final product?
  - Design efforts? Analysis efforts?
  - Testing campaigns? Test facilities, test articles (component, system, samples).
  - Manufacturing plans? Development/fabrication partners?

- **Preliminary program schedule**

- **Preliminary listing of known development risks**
  - Where are the expected technical or programmatic challenges and what is being done to mitigate these potential issues?

- **Description of vision for NASA partnering/insight with minimal interference**

Thank you

- **Thank you for your proposal and for making the trip to the NASA Marshall Space Flight Center**

- **We hope that your visit will be productive and memorable**